Quiz 1 Chemical Engineering Thermodynamics January 16, 2015

- 1)
- 9. Can an ideal gas condense? Can real fluids that follow the ideal gas law condense?
- 2)
- 1.13 A gas stream entering an absorber is 20 mol% CO₂ and 80 mol% air. The flowrate is 1 m³/min at 1 bar and 360 K. When the gas stream exits the absorber, 98% of the incoming CO₂ has been absorbed into a flowing liquid amine stream.
 - (a) What are the gas stream mass flowrates on the inlet and outlets in g/min?
 - (b) What is the volumetric flowrate on the gas outlet of the absorber if the stream is at 320 K and 1 bar?

Molar mass: CO2 = 44.0 g/mole, Air = 28.8 g/mole, R = 8.31e-5 bar m³/(K mole)

3)

- 1.18 Two kg of water exist initially as a vapor and liquid at 90°C in a rigid container of volume 2.42 m³.
 - (a) At what pressure is the system?
 - (b) What is the quality of the system?
 - (c) The temperature of the container is raised to 100°C. What is the quality of the system, and what is the pressure? What are Δ<u>H</u> and Δ<u>U</u> at this point relative to the initial state?
 - (d) As the temperature is increased, at what temperature and pressure does the container contain only saturated vapor? What is Δ<u>H</u> and Δ<u>U</u> at this point relative to the initial state?
 - (e) Make a qualitative sketch of parts (a) through (d) on a P-V diagram, showing the phase envelope.

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E.9 PROPERTIES OF WATER¹

I. Saturation Temperature

854 Appendix E Thermodynamic Properties

2

Answers Quiz 1 Chemical Engineering Thermodynamics January 16, 2015

1)

9. Can an ideal gas condense? Can real fluids that follow the ideal gas law condense?

An ideal gas cannot condense since there are no attractive forces between the gas molecules or atoms. A real gas that follows the ideal gas law can condense since it only has ideal behavior over a limited range of temperature and pressure. At some low temperature or high pressure the attractive potential between molecules will be stronger than 3kT/2 and the molecules will condense.

2)

- 1.13 A gas stream entering an absorber is 20 mol% CO₂ and 80 mol% air. The flowrate is 1 m³/min at 1 bar and 360 K. When the gas stream exits the absorber, 98% of the incoming CO₂ has been absorbed into a flowing liquid amine stream.
 - (a) What are the gas stream mass flowrates on the inlet and outlets in g/min?
 - (b) What is the volumetric flowrate on the gas outlet of the absorber if the stream is at 320 K and 1 bar?
 - a) n = PV/RT = 1 bar * 1 m³/min/(8.31e-5 bar m³/(K mole) 360K) = 33.4 mole/min with 20% C0₂ = 6.7 mole/min and 26.7 mole/min air. In exit stream you have 0.02*6.7 mole/min CO₂ = 0.1 mole/min and 26.7 mole/min air. CO₂ molecular weight is 44.0 g/mole and air has an average molecular weight of 28.8 g/mole. So mass rate of the incoming stream is 6.7 mole/min * 44.0 g/mole + 26.7 mole/min * 28.8 g/mole = 1.06 kg/min. Exit stream has 0.1 mole/min * 44.0 g/mole + 26.7 mole/min * 28.8 g/mole = 0.77 kg/min.

b) dV/dt = 26.8 moles/min 8.31e-5 bar m³/(K mole) 320K/1 bar = 0.713 m³/min

3)

- 1.18 Two kg of water exist initially as a vapor and liquid at 90°C in a rigid container of volume 2.42 m³.
 - (a) At what pressure is the system?
 - (b) What is the quality of the system?
 - (c) The temperature of the container is raised to 100°C. What is the quality of the system, and what is the pressure? What are Δ<u>H</u> and Δ<u>U</u> at this point relative to the initial state?
 - (d) As the temperature is increased, at what temperature and pressure does the container contain only saturated vapor? What is Δ<u>H</u> and Δ<u>U</u> at this point relative to the initial state?
 - (e) Make a qualitative sketch of parts (a) through (d) on a P-V diagram, showing the phase envelope.

- a) 0.070 MPa from the Saturation Temperature table.
- b) $V = 2.42/2 = 1.21 \text{ m}^3/\text{kg}$. $V_L = .0010 \text{ m}^3/\text{kg} V_V = 2.36 \text{ m}^3/\text{kg} q = (V-V_L)/(V_V-V_L)=1.21/2.36 = 0.51$
- c) At 100°C the pressure is 0.101 MPa from Saturation Temperature table. $V_L = .001 \text{ m}^3/\text{kg}$ $V_V = 1.67 \text{ m}^3/\text{kg}$ $q = (V-V_L)/(V_V-V_L)=1.21/1.67 = 0.72$

At 100°C H_L = 419, Δ H = 2260kJ/kg so H = 419 + 0.72 * 2260 kJ/kg = 2050 kJ/kg At 80°C H_L = 335, Δ H = 2310kJ/kg so H = 335 + 0.51 * 2310 kJ/kg = 1510 kJ/kg So, Δ H = 1510 kJ/kg - 2050 kJ/kg = -540kJ/kg

At 100°C U_L = 419, ΔU = 2087kJ/kg so U = 419 + 0.72 * 2087 kJ/kg = 1920 kJ/kg At 80°C U_L = 335, ΔU = 2147kJ/kg so U = 335 + 0.51 * 2147 kJ/kg = 1430 kJ/kg So, ΔU = 1430 kJ/kg - 1920 kJ/kg = -490kJ/kg

d) From the saturated table the temperature where the specific volume for the vapor phase is $1.21 \text{ m}^3/\text{kg}$ is 110°C . At that point the liquid enthalpy is 461kJ/kg and the liquid internal energy is also 461 kJ/kg. so $\Delta H = 461-1510\text{kJ/kg} = -1049 \text{ kJ/kg}$ and $\Delta U = 461 - 1430 \text{ kJ/kg} = -969 \text{ kJ/kg}$.

